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## **Application of Systems Analysis in the U.S. Department of Defense**

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INSTITUTE FOR DEFENSE ANALYSES

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## **PREFACE**

This document is an annotated version of a briefing to be given at the Defense Analysis Seminar X (DAS X), to be held 25–28 October 1999 in Seoul, Korea. The seminar is sponsored by the Deputy Under Secretary of the Army, Operations Research, and will be held at the Korea Institute for Defense Analyses. The contents of the briefing are solely the opinions of the author and do not represent the positions of either the Institute for Defense Analyses or the U.S. DoD.

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# **Application of Systems Analysis in the U.S. Department of Defense**

***A Presentation at DAS X  
by  
Dr. Stephen J. Balut  
October 1999***

Good morning. I'm Steve Balut, the Director of the Cost Analysis and Research Division at the Institute for Defense Analyses. I will talk about the invention of systems analysis and its application by the United States (U.S.) Department of Defense (DoD).

## **Outline**

- Leading events
- Invention and rapid expansion
- Weaknesses
- Curtailed use
- Strengthened process
- Reemergence
- Lessons

This slide displays an outline of my talk. I will describe the environment in which systems analysis first appeared, grew in importance and use, then stumbled, and eventually recovered.

Systems analysis was invented about 50 years ago. I will describe events leading to its invention and the rapid expansion in use of systems analysis throughout the U.S. DoD, and eventually in all U.S. federal agencies. This powerful analytical technique was implemented rapidly and before the knowledge and experience necessary to its successful use were in place. As a result, some early systems analyses resulted in faulty decisions with bad outcomes, which angered the U.S. Congress and embarrassed the DoD. The DoD abruptly curtailed the use of systems analysis until the needed more knowledge and experience were gained. About 10 years ago, a strengthened process reemerged that has been widely applied since. I will close by telling you about lessons we learned along the way. These lessons might be useful to you as you implement this powerful analytical technique.

## **Definition of Terms**

A “program” is a multi-year description of military capability in terms of resources (people, facilities, equipment, and dollars) needed to accomplish a defined military objective

Before going any further, I want to make sure you understand the meaning of a term that I will use throughout this presentation.

The term “program” can mean different things and is used in different ways. In *this* discussion, “program” means a multi-year description of military capabilities—in terms of resources—that are planned to accomplish a defined military objective. Resources include people, facilities, equipment, and dollars. Said another way, a program is the total set of resources planned to accomplish a defined set of military functions.

When I refer to the “Navy Program,” for example, I mean the collection of all people, facilities, equipment, and dollars needed to perform the missions assigned to the Navy. When I refer to the “Defense Program,” I mean the aggregation of the programs from each Military Department.

Now, on with the presentation.



## Leading Events (1940s)

- Scientists enlisted to help with war effort
- Operations research invented
- After war, military departments preserved scientific expertise
- "Think tanks" established

Systems analysis was invented shortly after World War II. Key events during and after the war created the *demand* and the *environment* that gave birth to systems analysis. The key events are listed on this slide.

Shortly after the start of the war, the governments of the Allied Forces, particularly the United Kingdom and the United States, enlisted scientists to aid the war effort. These scientists studied the operations of war in a quantitative, scientific way. These important studies laid the groundwork for the later invention of systems analysis.

The objective was to improve the efficiency of operations in progress or planned for the future. This line of study came to be called "operations research." Operations research sought no more than to do something *better*; to use scientific methods to *get the most* out of available resources.

During the war, the U.S. Military Departments had well-defined and well-understood missions—the Army's mission was land warfare; the Navy's mission was power projection from the sea, and the Army Air Corps's mission was air superiority, bombing, and combat support. But after the war, the distinction between mission responsibilities became blurred and eventually broke down. This was due to both the rapid development of military technology and the evolving character of the military opposition. Inter-service competition for missions became fierce. President Harry S. Truman tried to

limit this competition. In 1947, the U.S. DoD and Joint Chiefs of Staff (JCS) were established. With the establishment of the DoD, a cabinet-level office *headed by a civilian* was given the responsibility for allocating defense budgets to the military services. The JCS assisted the new Secretary of Defense identify which missions would be performed by each service.

During and after the war, the military departments took steps to institutionalize and preserve the scientific talents and resulting operations research capabilities that were brought to bear so successfully on the war effort. To do this, several defense research and analysis organizations—so-called “think tanks”—were established.

Three groups of scientists that had worked on Navy problems were later consolidated to form the Center for Naval Analyses (CNA). In 1947, the Army Air Corps established the RAND Corporation. RAND’s purpose was “to maintain scientific expertise...and to conduct independent and objective national security research....” At about the same time, the Weapon Systems Evaluation Group was formed to assist the newly formed JCS. The group’s purpose was “...to perform technical analyses of service and multi-service weapon systems.” The Institute for Defense Analyses (IDA), the research organization I represent, was established several years later to augment and eventually take over and expand on the Weapon Systems Evaluation Group’s mission. Additional organizations were formed, both within and outside the government, including professional scientific societies, to preserve and build on the expertise in operations research that existed at the end of the war.

## **Invention of Systems Analysis (Late 1940s)**

- Systems analysis grew out of operations research
- Economic principles applied to Air Force decisions
- Cost-effectiveness (CE) criterion of choice
- Cost analysis invented to support CE

In the late 1940s, the concept of conducting analysis from the perspective of the weapon systems being used grew naturally out of operations research. The original term “weapon systems analysis,” first coined at the RAND Corporation in 1948, was quickly shortened to “systems analysis.”

Systems analysis sought (and still seeks) to do all that operations research did—to use scientific methods to do something better, getting the most out of available resources—but it also sought to do the *right* thing better *and* more cheaply. Systems analysis thus sought to answer a more creative question than did operations research. It was oriented more toward the future and had a broader outlook.

RAND’s early systems analyses for the Air Force integrated economic principles with operations research. The basic analytical question of “Which system is best for the job?” changed to “Given a fixed budget, which system is most cost-effective?” A corollary is “Given a fixed level of effectiveness, which system can do the job most cheaply?” The use of dollar costs in these studies as a proxy for real, economic costs marked the birth of “cost-effectiveness analysis,” and cost analysis was a crucial component of the cost-effectiveness equation.

Cost-effectiveness was the heart and soul of systems analysis from the start. It was the criterion of choice.

Let's take a quick look at an early application of systems analysis to observe one of its early problems.

In 1949, RAND conducted the first large systems analysis for the Air Force. The analysis compared the prospective B-52 bomber to a turbo-prop alternative. Because RAND did not yet have a cost analysis capability, the Air Force provided RAND with the costs for both alternatives. RAND's analysis favored the turbo-prop, but the Air Force clearly wanted to buy the B-52. After RAND briefed its results to the Air Force, the Air Force dropped the cost of the B-52 by half and increased the cost of the turbo-prop by half. Needless to say, these changes tilted the analysis in favor of the B-52. The rest is history; the B-52 is still in the U.S. arsenal.

Some analysts at RAND felt they had been intentionally deceived by the Air Force. As a result, RAND established its own cost analysis department to ensure an independent cost analysis capability. Through the early 1950s, RAND analysts invented and refined the building blocks of cost analysis that continue to serve us today: the use of "one-time" and "recurring" costs, cost estimating relationships, parametric cost estimating, incremental costing, and force costing.

## **Contributing Factors (Late 1940s and 1950s)**

- RAND develops a Planning, Programming and Budgeting system for the Air Force
- Separation of service missions blurred
- Budget consciousness causes fierce competition for resources
- DoD moves toward management by mission
- Economic principles not used to allocate resources by the Office of the Secretary of Defense
- Civilian administration losing control of allocation of resources by mission

The use of the new analytical technique called systems analysis expanded rapidly. In retrospect, it may have expanded too rapidly. The reasons for its speedy acceptance and use had to do with the environment at the time in the U.S. DoD.

In the early 1950s, RAND developed a new expense accounting system for the Air Force. The new idea involved associating dollars with missions, (defense outputs) rather than functions (defense inputs) such as ammunition and fuel. This change led to a whole new approach to planning, programming, and budgeting resources for war.

Up to this point, the procedure for funding the U.S. defense program was as follows: Congress set aside an amount for national security, the Secretary of Defense divided it up among the services, and the services planned how to spend their allotted dollars on people, facilities, equipment, and operations to carry out their assigned missions.

This procedure worked well as long as the services had clearly defined and separated missions, which was the case through the end of World War II. However, during the late 1940s and 1950s, the distinction between these missions became blurred by rapid expansion of new technologies, such as nuclear power, and by the new threats posed by the different world order. It became increasingly clear that the procedure used to allocate defense resources would not work without a strong separation of missions.

Exacerbating the problem, President Dwight D. Eisenhower reduced the amount of money spent on national security during the 1950s. Smaller defense budgets created fierce competition for resources among the services.

To rectify the problem, the DoD took a few tentative steps away from management by service and towards management by mission. Unified commands were established on the basis of a mission rather than a theater. Unified commanders were given primary responsibility for operational control of associated forces.

But while the application of economic principles to defense decisions was beginning (thanks to RAND) in the Air Force, the rest of the DoD had not yet embraced the new technique.

By the late 1950s, civilian control over the military had clearly begun to weaken. Because of the practice of allocating dollars to the services when service missions were not separate, civilians in the Office of the Secretary of Defense had been losing control of the central political element of the defense program—the allocation of resources among missions. One solution proposed and rejected was to reorganize the services along mission lines. Another solution, proposed by RAND in 1954, 1956 and again in 1960, was to change *program control* from a service to a mission basis. Under this proposal, the services would compete with each other for major missions.

## **Application Expanded (Early 1960s)**

- PPBS implemented DoD-wide
- Use of systems analysis quickly expanded
- Military departments ill-prepared
- Low-cost systems won budget battles
- Use expanded to all federal agencies
- Organizational changes institutionalized process

In 1960, a book was published that led to changes in the way the DoD did business. The authors were Charles Hitch and Roland McKean, both of the RAND Corporation. The book, *Economics for Defense in the Nuclear Age*, described how to apply principles of economics to government (especially defense) decisions. Derived from RAND's development and application of systems analysis, the book addressed economic efficiency and stressed the need to compare costs and effectiveness. It also provided counter arguments to detractors. For example, here is a quote: "An economically efficient solution to military problems does not imply a cheap force or a small military budget. It simply implies that whatever the military budget, the greatest military capabilities are developed."

In 1961, President John F. Kennedy appointed Robert McNamara Secretary of Defense, who appointed Charles Hitch, one of the authors of the book, as DoD Comptroller. Hitch immediately established the position of Director for Systems Analysis, and appointed another RAND colleague, Alain Enthoven as the head. Enthoven, like Hitch, was part of the small group of analysts who had been developing the systems analysis technique at RAND over the previous 10 years.

Thus began a period in the DoD of rational and more centralized decision making under constrained budgets. Defense Comptroller Hitch initiated a defense-wide Planning, Programming and Budgeting System modeled after the Air Force's system. To quote the implementing directive, "the ultimate objective of the Planning, Programming, and Budgeting System shall be to provide operational Commanders-in-Chief the best possible mix of forces, equipment, and support attainable within fiscal constraints."

The defense program structure was immediately changed from being oriented around inputs (lists of things to buy, such as fuel and ammunition) to outputs (capabilities to perform missions, such as conventional warfare and strategic warfare).

The new Systems Analysis Office began examining proposed weapon systems in a systematic, rational manner using cost-effectiveness to support decisions. This early period in the development of basic cost analysis capabilities was marked by rapid expansion of financial management systems.

Due to the speedy introduction of this new criterion called cost-effectiveness, the services were not well prepared to present or defend their programs to the Office of the Secretary of Defense. The services learned quickly that low cost systems won budget battles, and high-cost systems were unlikely to be approved.

In 1965, President Lyndon B. Johnson directed all federal agencies to implement a Planning, Programming and Budgeting System. The implementing memorandum from the Bureau of the Budget directed that analysis comparing the benefits and costs of alternative programs be carried out before budget approval could be obtained.

Also in 1965, the Systems Analysis Office within the Office of the Secretary of Defense was elevated to the level of an Assistant Secretary of Defense. An economics division and a cost analysis division were established to improve the department's capabilities in those areas. By then, the Office of the Secretary of Defense had been conducting systems analyses for 5 years without benefit of these offices.



## **Weaknesses (Late 1960s)**

- Bad experiences
- Cost overruns
- Military leaders spoke out against systems analysis
- Limitations explained to Congress

Many important decisions were made in the early 1960s based on the results of systems analyses, most of which were conducted by the Office of the Secretary of Defense. Within a few years, it became clear in retrospect that some of those decisions had been bad ones. It also became clear that the DoD had rushed into the use of systems analysis without adequate preparation. That is, the tools required to conduct systems analysis successfully were not yet available. These included data and methods for forecasting both costs and effectiveness and people knowledgeable and experienced in the use of systems analysis.

The services continued to lose budget battles through the end of the 1960s. The Skybolt missile and B-70 bomber were canceled. The Minuteman missile procurement was reduced. The battle for NIKE missile program was lost. Navy escort ships were not approved. Approval of the Polaris submarine and missile system ended Air Force dominance of nuclear weapons. Some systems were forced on the services: the M-16 rifle was forced on the Army, and the F-4 fighter aircraft was forced on the Air Force.

By 1969, twenty-seven out of thirty-five major systems were exhibiting substantial cost growth. The DoD's ability to produce reliable cost estimates came into question, and Congress became less tolerant of cost overruns. Observers also noted poor choices of measures of effectiveness by analysts in the Systems Analysis Office. In some cases, the measures of effectiveness

used did not accurately reflect the true objectives of the analyses, resulting in biased and flawed findings and recommendations.

High-ranking military leaders, angry over the cost overruns, started speaking out in public against systems analysis. Here are two examples of what was said. General Ira Eaker: "one of the prime obstacles to adequate defense weapons...has been a hurdle called cost-effectiveness. This test applied by scientists and theorists has killed off many new weapons urgently needed by military leaders."

Another quote, by Admiral Hyman Rickover: "...decisions appear to be made by the rules that are ground out by the cost-effectiveness analysts. It never was the intent of the defense unification act that a group of analysts would, in effect, become the decision-making apparatus of our defense establishment. ... just what are the qualifications of the cost analysts? Their experience? Their accomplishments? Their reputations? ...the only record of accomplishments of these social scientists is reducing budgets."

In 1968, Secretary of Defense Schlesinger warned Congress of the limitations of economic analysis in national security issues in his memo titled "Uses and Abuses of Analysis."

## **Curtailed Use (1970s)**

- DoD decision making decentralized
- Systems Analysis Office downgraded; name and role changed
- Term "economic analysis" substituted for "systems analysis"

After nearly a decade of use, including some abuse, systems analysis earned a bad reputation, fell from favor, and was reeled in. Cost-effectiveness had been misused, sometimes out of ignorance, other times intentionally. The absence of tools to produce credible estimates made forecasting tenuous and policing of the process almost impossible. Something had to change in the way defense decisions were made to regain credibility with Congress and the American people.

In 1969, the Secretary of Defense made both procedural and organizational changes to de-emphasize the role of systems analysis at the level of the Office of the Secretary of Defense and return decision-making authority to the services. Rather than using systems analysis to initiate plans and systems, analysts in the Office of the Secretary instead were to passively "review" programs proposed by the services. The name of the Secretary's Systems Analysis Office was changed to "Program Review and Evaluation" to correctly describe their new role. The term "economic analysis" was substituted for "systems analysis" in key DoD directives. The effect of these changes was to shift the practice of systems analysis from the Office of the Secretary to the military departments. And, while the name was different, the procedure remained the same.

## **Strengthened Process (1970s and 1980s)**

- Resolve to fix procurement ills
- Milestones established
- Services directed to improve cost analysis capabilities
- Cost data collection systems initiated
- New rules/policies with regard to cost
- Cost organizations established

Starting in the early 1970s, defense managers took aggressive steps to fix the problems with defense procurement that they believed were caused by faulty systems analyses. These managers, determined to stop cost overruns, focused on improving capabilities to develop credible cost estimates. Major milestones were established for acquisition programs and cost reviews were required at each milestone. The Cost Analysis Improvement Group—or CAIG, as it is called—was established in the Office of the Secretary of Defense and independent cost estimates were required of this new group at the same time the services presented their cost estimates at milestone reviews. The services were directed to improve their cost analysis capabilities. Cost data collection systems were initiated to provide cost analysts with the information they needed to reduce error in their estimates.

In the early 1980s, Deputy Secretary of Defense Carlucci initiated a long list of actions aimed at improving the department's ability to forecast future costs. These actions included requiring explicit consideration of cost risk and uncertainty, budgeting to most likely or expected costs, use of economic production rates, allowing multi-year procurement based on benefit/risk analysis, and budgeting more realistically for inflation.

In 1984, Congress directed the Secretary of Defense to consider an independently derived life-cycle-cost estimate before approving either the development or production of any new weapon system. In response, the

Secretary of Defense provided resources to establish cost analysis centers and agencies in each of the military departments and required them to produce these independent estimates.

## **Reemergence (1990s)**

- Decisions on major issues supported by cost-effectiveness studies
- COEA's required by DoD Directive
- Now called "analysis of alternatives" (AOA)

With time and concerted effort, the U.S. DoD's abilities to conduct cost-effectiveness analyses improved and its use expanded. The department invested in improving its cost analysis skills, and these investments paid off. Research sponsored and conducted by cost analysis organizations in the Office of the Secretary and in the services improved both the data and methods used to forecast future costs. These research efforts were supported by contractors like RAND and IDA. The size of cost overruns declined as these capabilities improved.

At about this time, responsibility for conducting independent cost estimates for Major Weapon System Milestone Reviews shifted from the military departments to the Office of the Secretary of Defense. The CAIG now develops and presents these independent estimates, and the military departments now present what is referred to as "Service Cost Positions."

Through the late 1980s and the 1990s, large-scale systems analyses were increasingly conducted with the help of contractors, such as IDA, RAND, and CNA, who have special relationships with government offices.

Starting in 1991, systems analyses were required by DoD Directive, but under yet another name. The new name, "cost and operational effectiveness analysis," was a much more descriptive term than "economic analysis," which had been substituted for "systems analysis" 12 years earlier.

More recently—within the past few years—systems analysis has been practiced at all levels within the DoD under the name “analysis of alternatives.” In these most recent studies, analysts representing the Office of the Secretary of Defense, the military departments, and contractors collaborate to conduct the analyses.

## **Lessons**

Systems analysis is a powerful technique for aiding public sector decisions; however,...

- Building blocks must be in place before implementation
  - Cost data and methods
  - Tools to conduct effectiveness studies
  - People trained/experienced in application
- Must guard against misuse

Looking back, we can all learn from the U.S. experience. Systems analysis is unquestionably a powerful tool for shedding light on the most important issues associated with a decision to allocate public funds. Government decision-makers are better prepared to make good choices after considering both the costs and effectiveness of alternatives. However, the U.S. experience clearly demonstrates that arithmetic can be misused and abused, leading to faulty, costly decisions. We have learned that analysts cannot conduct credible systems analyses without first doing some homework. That is, certain building blocks should be in place before applying the technique.

One of the most troublesome areas has been costs. When systems analysis was first applied, cost analysis had not yet been invented. The DoD did not know how to forecast future costs of weapon systems, and that ability was developed slowly. Along the way, many bad cost estimates made their way into cost-effectiveness studies. Eventually, actual cost experiences showed the poor quality of these estimates. This practice resulted in embarrassing and destructive cost overruns that robbed future budgets to pay off debts that had grown larger than planned.

The other troublesome area was effectiveness. Measures of effectiveness used were sometimes faulty, and models for projecting the effectiveness of future systems had yet to be developed.



A more rational approach would have been to develop at least basic capabilities to forecast both cost and effectiveness before implementing systems analysis throughout the department. These basic capabilities would include data, methods, and tools, along with people trained and experienced in their use.

Given fundamental skills, tools, and information, the Office of the Secretary would have been better prepared to police the practice, making sure that systems analysis was not misused.

That concludes my presentation.

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